CLAIMS

We claim:

1. A surgical system comprising:

a robot connected to a bone, with which is associated an orthopaedic insert having at least one predrilled hole for attaching said insert to said bone;

a drill guiding plate carried by said robot, said guiding plate having at least one hole for guiding a drill into said bone and through said at least one predrilled hole;

an imaging system generating at least one image including said drill guiding plate and said at least one predrilled hole; and

a computational system utilizing data from said at least one image to align said robot such that the axis of said at least one hole defined by said drill guiding plate is aligned essentially colinearly with the axis of said at least one predrilled hole defined by said insert.

2. A surgical system according to claim 1 and wherein said axis of said at least one hole defined by said drill guiding plate is aligned essentially colinearly with the axis of said at least one predrilled hole both laterally and in angular orientation.

3. A surgical system according to either of claim 1 and 2 and wherein said drill guiding plate comprises a plurality of fiducial markers disposed in a predetermined pattern.

4. A surgical system according to claim 3 and wherein said imaging system utilizes said plurality of fiducial markers to align said drill guiding plate by means of said robot such that it images said drill guiding plate in a fronto-parallel orientation.

5. A surgical system according to any of claims 1 to 4, and wherein said imaging system is aligned such that it images said at least one predrilled hole in a fronto-parallel orientation.

6. A surgical system according to claim 5 and wherein said computational system aligns said robot by utilizing data from only one image of said imaging system.

7. A surgical system according to any of claims 1 to 6 and wherein said robot is directly mounted on said bone.

8. A surgical system according to any of claims 1 to 6 and wherein said robot is attached to said insert associated with said bone.

9. A surgical system according to any of claims 1 to 8 and wherein said robot maintains its position relative to said bone such that tracking of said bone position is obviated.

10. A surgical system according to any of claims 1 to 8 and wherein said robot maintains its position relative to said bone such that immobilization of said bone is obviated.

11. A surgical system according to any of claims 1 to 10 and wherein said bone is a long bone, and said orthopaedic insert is an intramedullary nail, and said at least one predrilled hole is a distal locking hole.

12. A surgical system according to claim 11 and wherein said robot is attached to the proximal end of said intramedullary nail.

13. A surgical system according to any of claims 1 to 10 and wherein said orthopaedic insert is an externally attached connector plate, and said at least one predrilled hole is a connecting hole.

14. A surgical system according to claim 13 and wherein said bone is a femur, and said connector plate is a percutaneous compression plate, and said connecting hole accommodates a screw for connecting said plate to the shaft of said femur.

15. A surgical system according to claim 13 and wherein said bone is a femur, and said connector plate is a percutaneous compression plate, and said connecting hole accommodates a screw for connecting a fractured head of said femur to its shaft.

16. A surgical system according to any of claims 1 to 13 and wherein said imaging system comprises an image intensifier with a calibration ring assembly, adapted to enable at least one of image distortion correction and camera calibration.

17. A surgical system according to any of claims 1 to 16 and wherein said robot comprises a miniature parallel robot.

18. A surgical system according to claim 17 and wherein said robot comprises at least three actuators mounted on a base member, said actuators being configured for at least one of translational and rotational movement.

19. An imaging system comprising:

a radiation source for illuminating a target to be imaged, said target having at least one predefined hole;

a target guide having at least a second predefined hole, whose axis is to be brought into coincidence with the axis of said at least one predefined hole of said target;

a robot on which said target guide is mounted, for bringing the axes of said at least one target guide hole and said at least one target hole into coincidence;

an image intensifier generating images of said target and said target guide; and

a computation system comprising:

a first position localizing module, which computes the position of said at least one target guide hole from an image thereof;

a second position localizing module, which computes the position of said at least one target hole from an image thereof; and

a registration unit adapted to determine a spatial relationship between said at least one target guide hole and said at least one target hole.

20. An imaging system according to claim 19, and wherein said image intensifier is aligned in a fronto-parallel setup, such that said registration unit determining said spatial relationship between said at least one target guide hole and said at least one target hole, utilizes a two-dimensional image only.

21. An imaging system according to claim 20, and wherein said image intensifier is aligned in a fronto-parallel setup by determining when an image of said at least one target hole has a minimum elliptic shape.

22. An imaging system according to claim 19, and wherein said image intensifier incorporates distortion correction and camera calibration functions.

23. An imaging system according to claim 19, and also comprising a calibration ring assembly for distortion correction and camera calibration.

24. An imaging system according to claim 19, and wherein said target guide comprises a predetermined pattern of fiducial markers, the images of which are

utilized by said first position localizing module in said computing the position of said at least one target guide hole.

25. An imaging system according to claim 24, and wherein said first position localizing module, which computes the position of said at least one target guide hole, comprises:

(i) a fiducial marker position locator and position template determiner;

(ii) an image generator producing a new image of said target guide, comprising said at least one image of said target guide from which said positions of said fiducial markers have been morphologically removed;

(iii) a normalized cross correlation calculator for said template at pixel locations with negative values, determining the centers of said fiducial markers;

(iv) a fiducial searcher for looking in small areas around local maxima found by said normalized cross correlator; and

(v) a position locator for said targeting guide localization, from the locations of said fiducials determined in step (iv).

26. The imaging system according to claim 25, and wherein said fiducial marker position locator and position template determiner utilizes a Hough transform method.

27. The imaging system according to claim 25, and wherein said position locator utilizes a principal component analysis procedure.

28. An imaging system according to claim 19, and wherein said second position localizing module, which computes the position of said at least one target hole from an image thereof, comprises:

(i) a contour locator using an edge detection routine, for determining the longitudinal contours of said target;

(ii) a hole searcher, determining the position of holes in an area between said longitudinal contours in an image of said target, using a detector for regions with the maximal number of edge elements in windows of dimensions similar to that of said hole moved over said contour; and

(iii) an ellipse fitter for said edge elements in each of said regions detected.

29. An imaging system according to claim 19, and wherein said edge detection routine is a Canny edge detector with sub-pixel edge localization.

30. An imaging system according to claim 19, and wherein said registration unit adapted to determine a spatial relationship between said at least one target guide hole and said at least one target hole, comprises:

an aligner to bring said image intensifier to a fronto-parallel configuration such that said at least one image of said target hole has a minimal elliptic shape;

a target guide aligner routine, such that said at least one image of said target guide hole has a minimal elliptic shape; and

a target guide lateral translator so that the positions of the axes of said target guide hole and said target hole coincide.

31. In an imaging system, a method of bringing the positions of the axes of a hole defined by a target guide and a hole defined by said target into coincidence, comprising the steps of :

localizing the position of said target guide hole from at least one image thereof;

localizing the axis of said target hole from at least one image thereof; and

registering said localized target guide hole with said axis of said target hole.

32. The method of claim 31, and also comprising the initial step of image distortion correction and calibration of an imaging system utilized to obtain said images of said target guide hole and said target hole.

33. The method of either of claims 31 and 32, wherein said target guide comprises a predetermined pattern of fiducial markers, and said localizing the position of said target guide hole is performed by determining the imaged position of said fiducial markers in said target guide.

34. The method of claim 33, wherein said determining the imaged position of said fiducial markers in said target guide comprises the steps of:

(i) detecting the positions of said fiducial markers and inferring a template from their positions;

(ii) generating a new image of said target guide, comprising said at least one image of said target guide from which said positions of said fiducial markers have been morphologically removed;

(iii) computing a normalized cross correlation value of said template at pixel locations with negative values to determine the centers of said fiducial markers;

(iv) searching for fiducials in a small area around local maxima of said normalized cross correlation; and

(v) determining the position of said targeting guide from the locations of said fiducials determined in step (iv).

35. The method of claim 34, wherein said step of detecting the positions of said fiducial markers is performed using a Hough transform.

36. The method of claim 34, wherein said step of determining the position of said targeting guide from the locations of said fiducials is performed using a principal component analysis procedure.

37. The method of either of claims 31 and 32, wherein said localizing the axis of said target hole from at least one image thereof is performed by the steps of:

(i) locating the longitudinal contours of said target using an edge detection routine;

(ii) searching for a hole in an area between said longitudinal contours in an image of said target by detecting regions with the maximal number of edge elements in windows of dimensions similar to that of said hole moved over said contour; and

(iii) fitting an ellipse to said edge elements in each of said regions detected.

38. The method of claim 37 wherein said edge detection routine is a Canny edge detector with sub-pixel edge localization.

39. The method of either of claims 31 and 32, wherein said registering said localized target guide hole with said axis of said target hole is performed by the steps of:

adjusting said imaging system to a fronto-parallel configuration such that said at least one image of said target hole has a minimal elliptic shape;

aligning said target guide such that said at least one image of said target guide hole has a minimal elliptic shape; and

translating said target guide laterally so that the positions of the axes of said target guide hole and said target hole coincide.